WELDING GUIDELINES FOR

DUPLEX & SUPERDUPLEX

STAINLESS STEELS

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Welding Consumables for
Duplex & Superduplex Alloys

Stainless Steels

Duplex & superduplex ferritic-austenitic stainless steels

Welding guidelines

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Duplex & superduplex ferritic-austenitic stainless steels

Welding guidelines

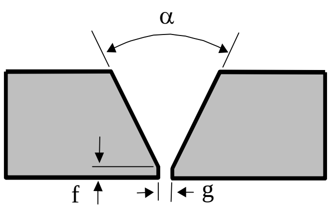
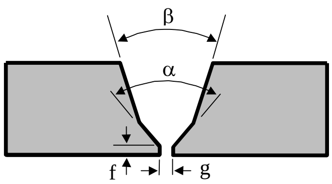
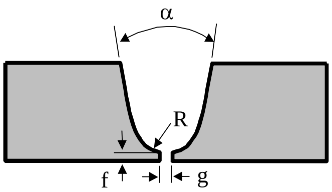
1 Introduction

There is a range of stainless steel alloys with a duplex, ferritic-austenitic, microstructure and this leaflet provides guidance on welding these alloys. Standard duplex is 22%Cr (eg. UNS S31803 and S32205) and superduplex is 25%Cr with a pitting resistance equivalent number (PRE_N) ≥40 (eg. UNS S32760, S32750 and S32550). These guidelines are based on joints being left in the as-welded condition. Metrode have a full range of consumables, and data sheets for all products are included at the end.



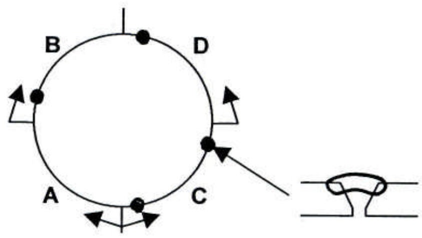

2 Joint preparation

The joint preparations will be similar to those used for standard stainless steel fabrication but for single sided joints it is important to have an open root gap to ensure the addition of adequate filler. The joint preparation will vary depending on material thickness, see examples below.

	Wall Thickness mm	*Included angle, α*	*Included angle, β*	*Root gap, g mm*	*Root face, f mm*
	2 – 3	70 – 90	-	2 – 3	0.5 – 1.5
	> 4	65-75	-	2 – 4	0.5 – 1.5
	> 20	70 – 80	15 – 20	2 – 4	0.5 – 1.5
	> 20	15 – 30	Radius, R mm 4 – 6	2 – 4	0.5 – 1.5

Tacking

Tacking is important to ensure the root gap does not close. Bullet tacks or bridging tacks are normally used and must be removed as each segment is completed. All tacks should be deposited following an approved weld procedure. There must be sufficient tacks evenly spaced round the joint to keep a consistent root gap.



3 Preheat

Preheat is not necessary for most duplex and superduplex stainless steel joints unless the material is below ~5°C or wet, in which case the material should be preheated (~75-100°C) to prevent condensation. Heating must be uniform avoiding the creation of localised hot spots.

Some thick section joints to be welded with sub-arc may benefit from a low preheat of ~75-125°C. On large, thick section joints, which have a significant heat sink the first submerged arc runs can be prone to pin-hole porosity; a low preheat can help prevent this.

4 Interpass temperature

The interpass temperature for both duplex and superduplex should be controlled to ensure the best results. For superduplex 150°C is the maximum but for 22%Cr duplex 250°C would probably be acceptable although most codes do not differentiate between duplex and superduplex so 150°C maximum should be used for all grades.

Forced air cooling

To improve productivity by reducing the time required to cool below the interpass temperature it is possible, on some joints, to use forced air cooling. The main application that has taken advantage of forced air cooling has been rotated submerged arc joints; because in situations where welding is carried out continuously there is a risk of excessive heat build-up, this can be minimised by forced cooling. Dried compressed air can be passed through the centre of the pipe once the gas purge has been removed.

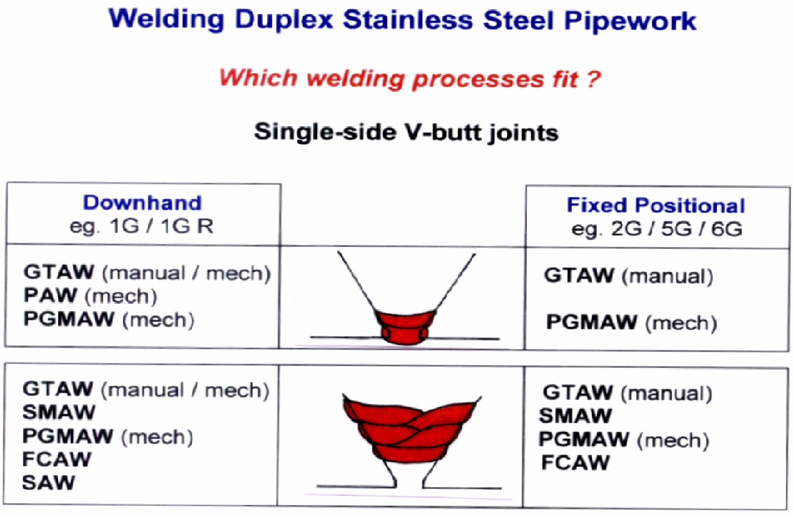
5 Heat input

Heat input needs to be kept within specified limits to ensure optimum properties. Heat inputs in the range 0.5-2.5kJ/mm for duplex and 0.5-2.0kJ/mm for superduplex should be acceptable, but most codes restrict the maximum to 1.75 or 2.0kJ.mm for duplex and 1.5 or 1.75kJ/mm for the superduplex grades.

A maximum heat input is imposed to prevent overheating of the HAZ and previously deposited weld metal. High heat inputs also produce slower cooling rates which, particularly in superduplex, increase the risk of intermetallic formation. Very low heat inputs should also be avoided because this will increase the number of runs required to fill a joint. If more runs are deposited the weld metal is reheated more times and this again increases the risk of intermetallic formation. A reasonable working range for the filling runs is about 1.0-1.75kJ/mm, depending on grade of material and thickness.

6 Welding processes

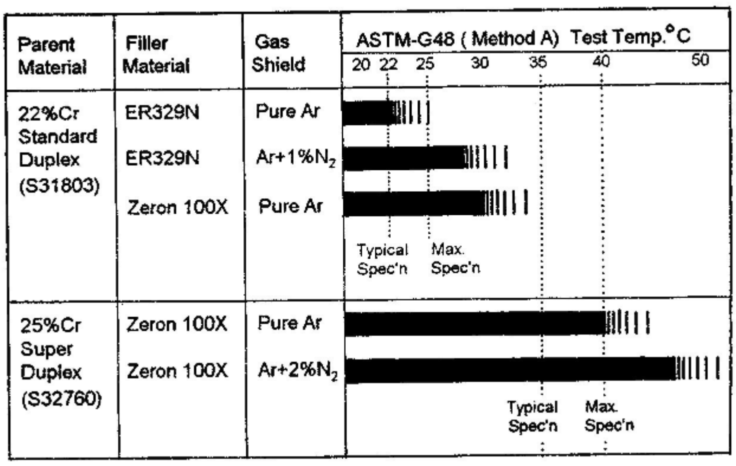
The joint can be considered in two parts – the root and the fill. The welding process and consumable selection should reflect this. The root requires a controllable welding process and filler capable of delivering the necessary corrosion resistance. The welding process for the filling runs can be selected to provide maximum productivity, and the consumable selected to deliver the required mechanical properties (strength and toughness). The range of suitable welding processes are summarised on the following page:



7 Root welding

Filler wire must always be added, root runs should not be made autogenously. Because of the control it allows root runs are nearly always deposited using the TIG process. The root run is critical in order to achieve good corrosion resistance so care should be taken to ensure the root is deposited correctly. The aim should be to add as much filler as practical within the heat input restrictions that are imposed. As a guideline the root run thickness should be ~2mm on thin wall tube (3-4mm) rising to 3 or 4mm as pipe thickness increases.

To ensure good corrosion properties (and good G48A performance) on 22%Cr duplex a superduplex filler wire is often used for the root run; this approach is recommended for G48A tests at +25°C. To optimise root corrosion performance in superduplex base material the superduplex filler can be used in conjunction with argon 1.5-2.5% nitrogen shielding gas; this approach is recommended if G48A testing is required at +40°C.

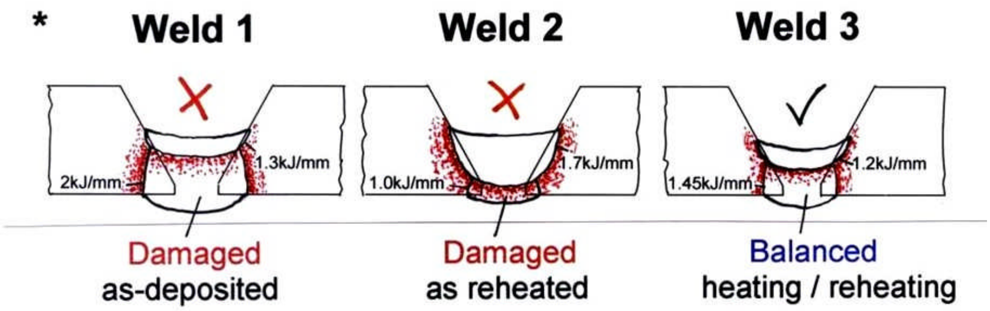


Purging

A gas purge must be used for root runs deposited using the TIG process and will normally be maintained for the first three layers or approximately 10mm of deposit. Commercially pure argon is generally used as the purge gas. Purge flow rates are determined by the pipe size but it is important that following the removal of tacks, grinding etc that the purge is allowed to stabilise again before welding. The efficiency of the purge should be monitored with an oxygen monitor to ensure the oxygen content is maintained below 0.5% oxygen.

8 2nd "cold" pass

The second pass is almost as important as the root run when it comes to ensuring good corrosion performance. The second pass should aim to be about 75% the heat input of the root run to prevent overheating of the root. The second pass should be a single run; the layer should not be split to two runs until at least the third layer.



9 Filling runs

TIG (GTAW)

For small diameter tubes and pipes TIG is often used for filling the joint but the TIG process can also be used for filling thicker wall pipes. The TIG process has the advantage of producing high quality weld metal and there is no slag to be removed. The productivity of the TIG process can be improved by using 3.2mm diameter wire.

Metrode has both a duplex (ER329N) and superduplex (Zeron 100X) wire. Commercial purity argon (99.995%) should be used as the shielding gas or possibly argon-helium mixtures if preferred; gases containing hydrogen should not be used. As mentioned earlier, for root runs in superduplex corrosion performance can be improved by using an argon shielding gas containing 1.5-2.5% nitrogen.

MMA (SMAW)

The MMA process is widely used because of its adaptability and simple equipment requirements. For positional pipe welding and for applications that have impact requirements Metrode have three basic coated electrodes: 2205XKS (duplex), 2507XKS and Zeron 100XKS (for superduplex). For applications where operability and ease of use are the most important factors then there are also two rutile coated electrodes: Ultramet 2205 (duplex) and Ultramet 2507 (superduplex).

MIG (GMAW)

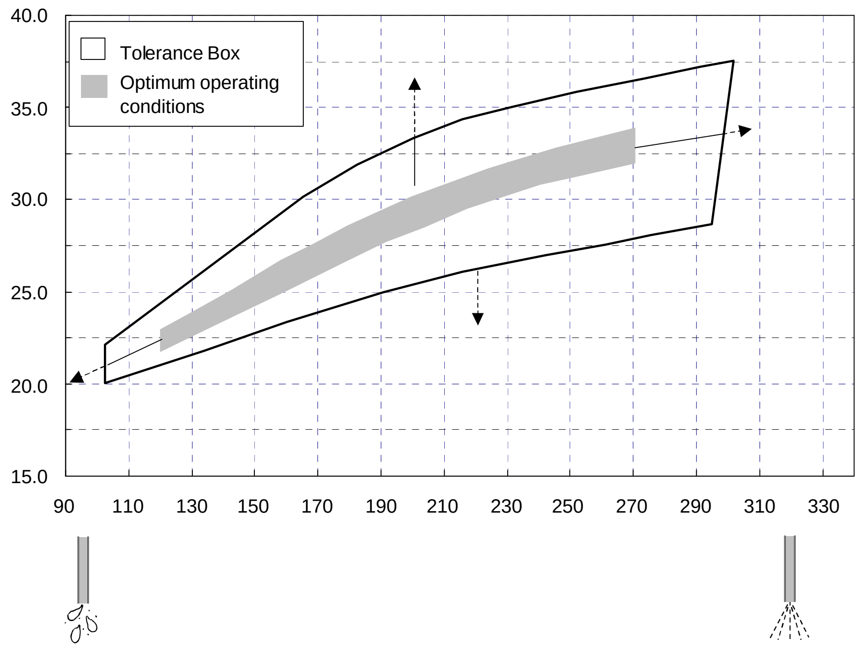
The MIG process has not been very widely used for duplex and superduplex. If the MIG process is to be used it must be in conjunction with a pulsed current power source. The shielding gas that has proved most successful is argon-35% helium-2% CO2 (there are a number of different proprietary gases on the market with compositions similar to this).

The spooled wire is also often used for mechanised or automatic TIG welding, and in these situations pure argon shielding gas is used.

FCAW

The flux cored arc welding process can provide productivity advantages over the TIG or MMA processes when material is over ~15mm thick and ~200mm diameter. The process can be used down to ~10mm wall thickness if the diameter is larger and ~150mm diameter if the wall thickness is great enough. There are both downhand and positional wires available: Supercore 2205 (downhand) and Supercore 2205P (positional) are the 22%Cr duplex wires; Supercore 2507 (downhand) and Supercore Z100XP and Supercore 2507P (positional) are the superduplex wires.

The wires are designed to be used with argon-20% CO2 shielding gas (M21 or M24 in BS EN 439), and although there are many proprietary gases that would be suitable the argon content should not exceed 80%. The downhand wires (Supercore 2205 and Supercore 2507) can also be used with 100% CO2 (C1 in BS EN 439). The gas flow rate required is 20-25 l/min. The wire stickout, or electrode extension, should be 15-20mm; for fixed pipe welding (ASME 5G/6G) it may be necessary to reduce the electrode extension to 12-15mm. The parameter box for the flux cored wires is shown below.



SAW

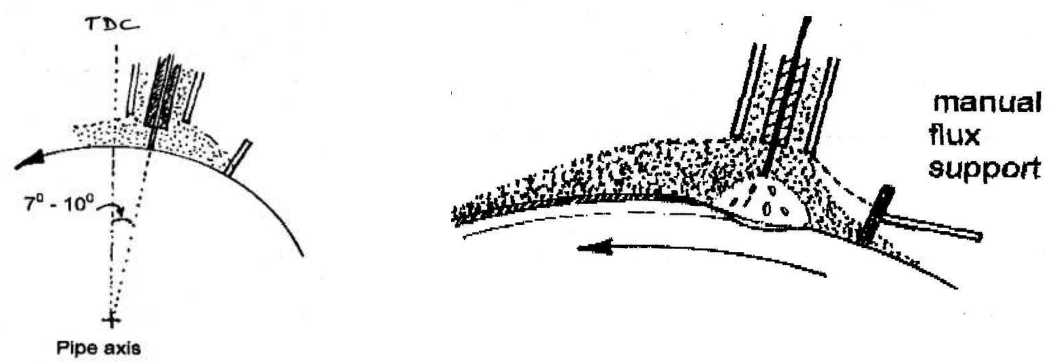
The submerged arc process provides the highest potential productivity using either 1.6mm or 2.4mm diameter wire. The process is only suitable for welding in the flat position so the component to be welded must be capable of being positioned in the flat or of being rotated. Before starting the submerged arc welding ~10mm of deposit needs to be built-up with another process (normally TIG or MMA) to prevent burn through, or overheating of the root run. Metrode have both duplex (ER329N) and superduplex (Zeron 100X) filler wires.

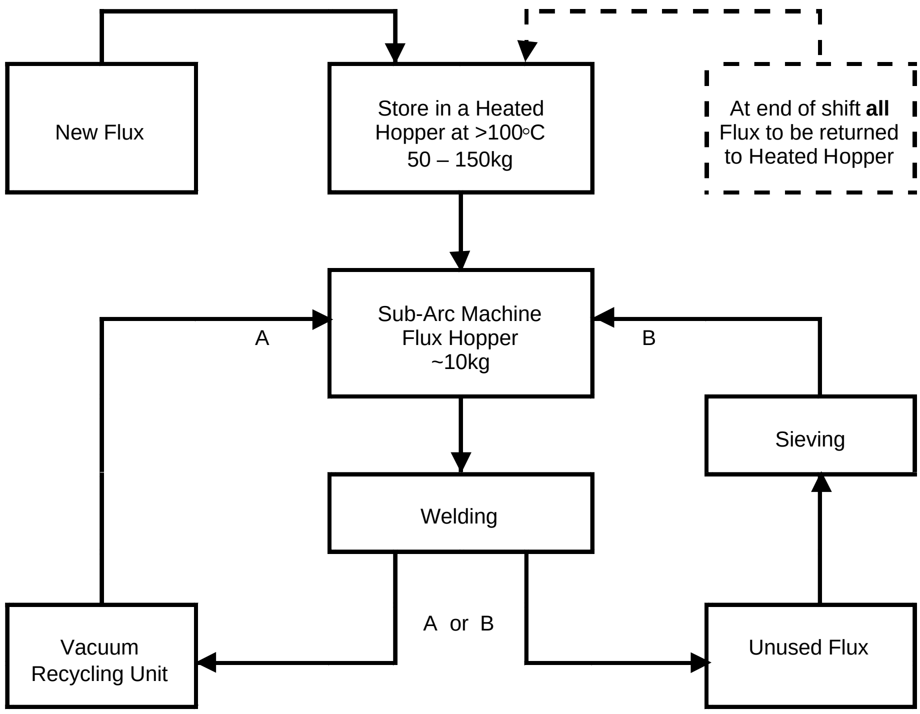
The process requires a separate flux and Metrode have two suitable fluxes: SSB and LA491. The wire stickout is maintained at ~20mm and the flux pile at ~25mm. Handling of the flux is also important, see next page. Typical welding parameters are:

1.6mm	275A	28V	300mm/min
2.4mm	350A	30V	350mm/min

These parameters are only a guideline and may need to be adjusted for specific applications.

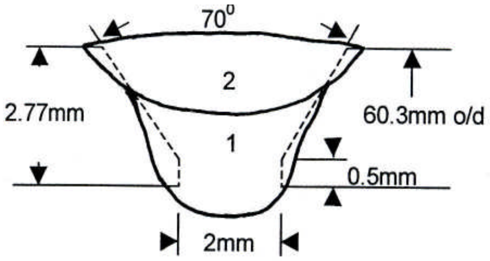
When submerged arc welding on a rotated pipe the torch should be positioned just before the top of the joint and be angled towards the centre, see below.

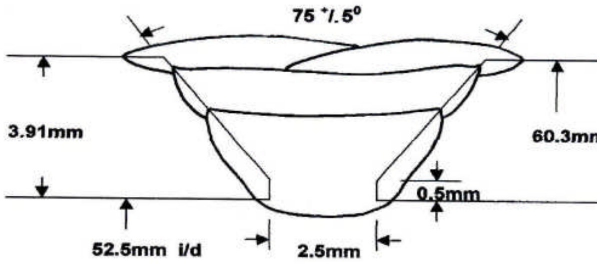




10 Thin wall tube

When welding thin wall tube it is even more critical to use a carefully controlled weld procedure because the tube can easily be overheated. The maximum interpass temperature should be reduced to 100°C. Even on small diameter tube the weld should be split into segments/quarters to prevent excessive heat build-up.





11 Post weld heat treatment

Most duplex and superduplex fabrication work in wrought material is left in the as-welded condition but major repairs to castings are generally specified in the solution annealed condition. Experience indicates good properties can be achieved with a heat treatment of 1120°C/3-6 hours followed by a water quench. Heat treatment, other than solution annealing, should not be carried out because duplex and superduplex alloys are prone to intermetallic formation.

12 Dissimilar welding

Each dissimilar combination has to be assessed on its own merit but some general recommendations can be made for a number of commonly encountered combinations.

	Superduplex	*22%Cr duplex*	*Nickel alloys*	*Austenitic stainless steel*	*Mild and low alloy steel*
Superduplex	Zeron 100 2507	22%Cr duplex (1)	Nickel alloy (eg. C22)	309Mo (2)	309L/309Mo (2)
22%Cr duplex	22%Cr duplex (1)	22%Cr duplex	Nickel alloy (eg. C22)	309Mo (3)	309L/309Mo (3)

(1) If it simplifies consumable selection and weld procedures superduplex consumables could be used.

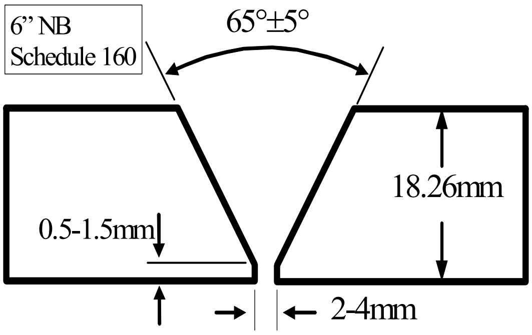
(2) If there are only a limited number of dissimilar joints the superduplex consumables could be used to simplify the weld procedures and consumable control.

(3) If there are only a limited number of dissimilar joints the duplex consumables could be used to simplify the weld procedures and consumable control.

Welding Procedure Specification (WPS)

Welding Procedure No: Superduplex TIG/GTAW

Consumables		Base Material	
Welding process (root):	TIG / GTAW	Parent Material:	Superduplex.
- Consumable:	**Zeron 100X**		(UNS S32750 & S32760).
- Specification:	BS EN 12072: W 25 9 4 N L		ASME IX: P or S number (QW422) =
Welding process (fill):	TIG / GTAW		10H group 1.
- Consumable:	**Zeron 100X**	Thickness:	18.26mm (Schedule 160)
- Specification:	BS EN 12072: W 25 9 4 N L	Outside Diameter:	6 inch NB
Joint Details		**Joint Position**	
Joint Type:	Single side butt	Welding Position:	ASME 6G
Manual/Mechanised:	Manual		

Joint Sketch	Welding Sequences
	Split layers (2 beads per layer) from runs 4/5 onwards.

Welding Details

Run	Process	Consumable	Diameter mm	Current A	Voltage V	Travel speed mm/min	Type of current / Polarity	Heat Input kJ/mm
1	TIG	Zeron 100X	2.4	80-100	~12	~50	DC-	~1.2
2	TIG	Zeron 100X	2.4	90-130	~12	~125	DC-	~0.8
Fill	TIG	Zeron 100X	3.2	200-225	~12	100-175	DC-	~1.5

Electrode Baking or Drying:	NA
Gas – root (TIG) shielding:	Ar + 2% N_2
backing:	Ar
Gas - fill/cap (TIG) – Shielding:	Ar
Purge:	Ar
Tungsten Electrode Type/Size:	2%Th/2.4mm
Details of Back Gouging/Backing:	NA

Preheat Temperature:	20°C
Interpass Temperature:	150°C max

Post-Weld Heat Treatment and/or Ageing:	None
Temperature:	
Time:	

Notes:

1. Tack joint securely to prevent root closure using four bridging tacks.
2. Weld pipe in four 90° segments to prevent excessive overheating.
3. Purge to maintain 0.5% oxygen max.
4. Ar + 2%N_2 shielding gas is recommended for the root run to ensure G48A properties.
5. Purging 20-30l/min (reduced to ~10l/min for tie-in). Maintain purge for first two runs.
6. Shielding gas flow rate 8-12l/min.

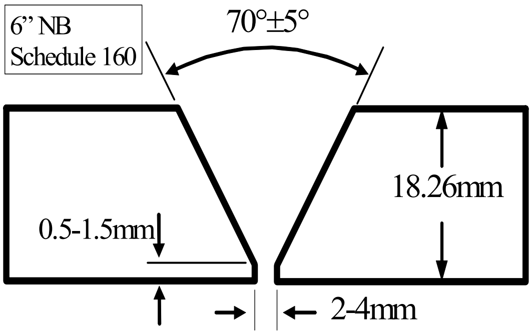
Welding Procedure Specification (WPS)

Welding Procedure No: Superduplex MMA/SMAW

Consumables		Base Material	
Welding process (root):	TIG / GTAW	Parent Material:	Superduplex.
- Consumable:	**Zeron 100X**		(UNS S32750 & S32760).
- Specification:	BS EN 12072: W 25 9 4 N L		ASME IX: P or S number (QW422) =
Welding process (fill):	MMA / SMAW		10H group 1.
- Consumable:	**Zeron 100XKS / 2507XKS**	Thickness:	18.26mm (Schedule 160)
- Specification:	BS EN 1600: E 25 9 4 N L B 4 2	Outside Diameter:	6 inch NB

Joint Details		Joint Position	
Joint Type:	Single side butt	Welding Position:	ASME 6G
Manual/Mechanised:	Manual		

Joint Sketch



Welding Sequences

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Welding Details

Run	Process	Consumable	Diameter mm	Current A	Voltage V	Travel speed mm/min	Type of current / Polarity	Heat Input kJ/mm
1	TIG	Zeron 100X	2.4	80-100	~12	~50	DC-	~1.2
2	TIG	Zeron 100X	2.4	90-130	~12	~125	DC-	~0.8
Fill	MMA	Zeron 100XKS / 2507XKS	3.2	75-95	~25	75-125	DC+	~1.2

Electrode Baking or Drying:	200°C/2 hours
Gas – root (TIG) shielding:	Ar + 2% N_2
backing:	Ar
Gas - fill/cap:	Not applicable
Tungsten Electrode Type/Size:	2%Th/2.4mm
Details of Back Gouging/Backing:	NA

Preheat Temperature:	20°C
Interpass Temperature:	150°C max

Post-Weld Heat Treatment and/or Ageing:	None
Temperature:	
Time:	

Notes:

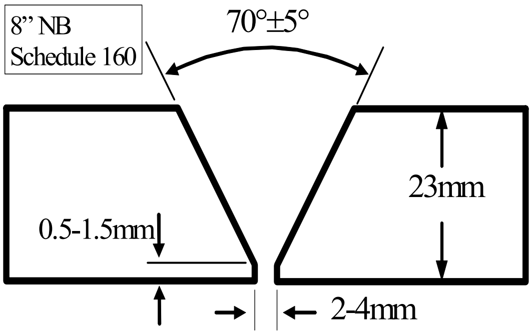
1. Tack joint securely to prevent root closure using four bridging tacks.
2. Weld pipe in four 90° segments to prevent excessive overheating.
3. Purge to maintain 0.5% oxygen max.
4. Ar + 2%N_2 shielding gas is recommended for the root run to ensure G48A properties.
5. Purging 20-30l/min (reduced to ~10l/min for tie-in). Maintain purge for first two runs.
6. Shielding gas flow rate 8-12l/min.

Welding Procedure Specification (WPS)

Welding Procedure No: Superduplex FCAW

Consumables			Base Material	
Welding process (root):		TIG / GTAW	Parent Material:	Superduplex.
	- Consumable:	**Zeron 100X**		(UNS S32750 & S32760).
	- Specification:	BS EN 12072: W 25 9 4 N L		ASME IX: P or S number (QW422) =
Welding process (fill):		FCAW		10H group 1.
	- Consumable:	**Supercore Z100XP / 2507P**	Thickness:	23mm (Schedule 160)
	- Specification:	--	Outside Diameter:	8 inch NB

Joint Details		Joint Position	
Joint Type:	Single side butt	Welding Position:	ASME 6G
Manual/Mechanised:	Manual		

Joint Sketch	Welding Sequences
	.

Welding Details

Run	Process	Consumable	Diameter mm	Current A	Voltage V	Travel speed mm/min	Type of current / Polarity	Heat Input kJ/mm
1	TIG	Zeron 100X	2.4	80-100	~12	~50	DC-	~1.2
2	TIG	Zeron 100X	2.4	90-130	~12	~125	DC-	~0.8
3-4	TIG	Zeron 100X	2.4	140-160	~12	~75	DC-	~1.5
Fill	FCAW	Supercore Z100XP/2507P	1.2	140-180	~26	100-175	DC+	~1.5

Electrode Baking or Drying:		NA
Gas – root (TIG)	shielding:	Ar + 2% N_2
	backing:	Ar
Gas - fill/cap (FCAW) – Shielding:		Ar-20% CO_2
Tungsten Electrode Type/Size:		2%Th/2.4mm
Details of Back Gouging/Backing:		NA

Preheat Temperature:	20°C
Interpass Temperature:	150°C max

Post-Weld Heat Treatment and/or Ageing:	None
Temperature:	
Time:	

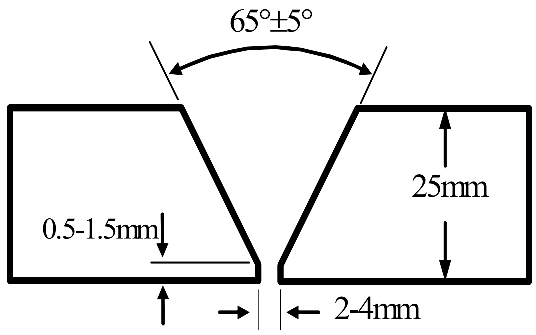
Notes:

1. Tack joint securely to prevent root closure using four bridging tacks.
2. Weld pipe in four 90° segments to prevent excessive overheating.
3. Purge to maintain 0.5% oxygen max.
4. Ar + 2%N_2 shielding gas is recommended for the root run to ensure G48A properties.
5. Purging 20-30l/min (reduced to ~10l/min for tie-in).
6. Shielding gas flow rate: TIG = 8-12l/min, FCAW = 20-25 l/min.

Welding Procedure Specification (WPS)

Welding Procedure No: Superduplex SAW

Consumables		Base Material	
Welding process (root):	TIG / GTAW	Parent Material:	Superduplex.
- Consumable:	**Zeron 100X**		(UNS S32750 & S32760).
- Specification:	BS EN 12072: W 25 9 4 N L		ASME IX: P or S number (QW422) =
Welding process (fill):	SAW		10H group 1.
- Consumable:	**Zeron 100X**	Thickness:	~25mm
- Specification:	BS EN 12072: W 25 9 4 N L	Outside Diameter:	Not applicable
Joint Details		**Joint Position**	
Joint Type:	Single side butt	Welding Position:	ASME 1G
Manual/Mechanised:	Mechanised		
Joint Sketch		**Welding Sequences**	



Split layers (2 beads per layer) from runs 4/5 onwards.

Welding Details

Run	Process	Consumable	Diameter mm	Current A	Voltage V	Travel speed mm/min	Type of current / Polarity	Heat Input kJ/mm
1	TIG	Zeron 100X	2.4	80-100	~12	~50	DC-	~1.2
2	TIG	Zeron 100X	2.4	90-130	~12	~125	DC-	~0.8
3-4	TIG	Zeron 100X	2.4	140-160	~12	~75	DC-	~1.5
Fill	SAW	Zeron 100X	2.4	300-400	~30	300-500	DC+	~1.5

Electrode Baking or Drying:	NA
Gas – root (TIG) shielding:	Ar + 2% N_2
backing:	Ar
Flux - fill/cap (SAW) –	LA491
Tungsten Electrode Type/Size:	2%Th/2.4mm
Details of Back Gouging/Backing:	NA

Preheat Temperature:	20°C
Interpass Temperature:	150°C max

Post-Weld Heat Treatment and/or Ageing:	None
Temperature:	
Time:	

Notes:

1. Tack joint securely to prevent root closure using four bridging tacks.
2. Purge to maintain 0.5% oxygen max.
3. Ar + 2%N_2 shielding gas is recommended for the root run to ensure G48A properties.
4. Purging 20-30l/min (reduced to ~10l/min for tie-in). Maintain purge for first two runs.
5. Shielding gas flow rate 8-12l/min.